Managing Nitrogen and Water In Agriculture

Monterey County
Water Resources
Agency

1850

Santa Clara Valley
Water District

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These "Fact Sheets" were designed as quick technical references for local growers. More detailed information is available from the original documents; please see the reference paragraph at the bottom of each Fact Sheet.

Fact Sheet 1 ***Fertilizer Management in Coastal Cool-Season Vegetables***

BEST MANAGEMENT PRACTICES:

- Evaluate Current Irrigation and Fertilization Practices and Plan Improvements in Management
- Base the Amount and Timing of N Fertilizer Applied on Crop Needs and Production Goals
- Place N Fertilizer Materials Where Maximum Plant Uptake Will Occur
- Minimize Leaching Losses of Nitrate During Non-Crop Periods

Fact Sheet 2 ***On-Farm Handling of Fertilizers***

BEST MANAGEMENT PRACTICES:

- Avoid Fertilizer Material Spills During All Phases of Transport, Storage, and Application

Fact Sheet 3 ***Water Management in Coastal Cool-Season Vegetables***

BEST MANAGEMENT PRACTICES:

- Evaluate Current Irrigation and Fertilization Practices and Plan Improvements in Management
- Operate Irrigation Systems to Minimize Deep Percolation and N Losses
- Improve Existing Furrow Irrigation
- Improve Existing Sprinkler Irrigation
- Improve Existing Drip Irrigation

Fertilizer Management in Coastal Cool-Season Vegetables

Fact Sheet 1

Evaluate Current Irrigation and Fertilization Practices and Plan Improvements in Management

- Determine the extent of nitrate contamination of ground water beneath or near crop fields and assess the potential for transport of soluble contaminants (nitrate, salts) downward to the ground water and laterally to surface waters.
- Develop and implement a system for keeping long-term records on each field of water and nutrient/soil amendment inputs, cultural operations, pest problems, land leveling or other improvements, and crop yield and quality.
- Review current cultural practices and develop improved nutrient and water management plans.

Base the Amount and Timing of N Fertilizer Applied on Crop Needs and Production Goals

- Before applying N early in the growth cycle, assess the amount of nitrate already present by soil (or soil solution) sampling and analysis.
- When applying manure shortly before a crop is planted, determine the nutrient content of the manure and the amount of nitrate already present in the soil. Apply manure at a rate consistent with the crop nutrient requirements.
- Split applications of N fertilizer.
- When possible, avoid water-running N fertilizer in the furrows. If fertilizer N must be water-run, maximize irrigation uniformity and inject fertilizer during the last half of the irrigation set.
- Use plant tissue sampling for mid- and late-season fertilizer decisions.
- Do not apply excessive single amounts of fertilizer N during the rainy season.
- For fertilizer application during fall tillage, use only low N-containing materials such as $N:P_2O_5:K_2O$ equal to 1:3:3. Higher N materials may be appropriate if a crop is to be planted soon.
- Measure nitrate levels in the irrigation water and adjust N fertilizer rate accordingly.

Place N Fertilizer Materials Where Maximum Plant Uptake Will Occur

- Incorporate N fertilizer into the crop bed by either placing fertilizer on or near the seed row and watering it in, knifing fertilizer into the bed, or broadcasting fertilizer and then listing it up into the bed.
- Incorporate manures and other organic amendments into soil with consideration of the timing of conversion of manure N to other forms.

Minimize Leaching Losses of Nitrate During Non-crop Periods

- If conditions permit, grow a cover crop rather than leaving fields fallow during the rainy season.

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These best management practices were excerpted and modified from the University of California Division of Agriculture and Natural Resources "Production Guide: Nitrogen and Water Management for Coastal Cool-Season Vegetables." This Fact Sheet is based on Management Measures 1, 3, 4, and 5 of the Production Guide. This publication can be ordered from ANR Communication Services at 800-994-8849 or on the Internet at http://commserv.ucdavis.edu/ucce/.

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On-Farm Handling of Fertilizers

Fact Sheet 2

Avoid Fertilizer Material Spills During All Phases of Transport, Storage, and Application

- When transporting fertilizer, do not overfill trailers or tanks. Cover or cap loads properly and display appropriate placards on vehicles.
- When transferring fertilizer into on-farm storage or into a fertilizer applicator, take care not to allow materials to accumulate on the soil. Good housekeeping practices shall be implemented to prevent contamination of groundwater and/or surface water.
- Clean up fertilizer spills promptly.
- Maintain all fertilizer storage facilities to meet government and industry standards and protect them from the weather.
- Shut off fertilizer applicators during turns and use check valves when possible.
- Maintain proper calibration of fertilizer application equipment.
- Whenever injecting fertilizer into irrigation water, ensure backflow does not occur.
- Distribute rinse water from fertilizer application equipment evenly throughout the field. Fertilizer tanks and equipment should be cleaned by rinsing in the field or at a properly designed wash facility. Rinse water and/or sludge should be evenly distributed throughout the field using good agronomic practices.
- When equipment is parked, use care to prevent material from leaking onto storage area. If equipment is known to be in disrepair, completely remove fertilizer material before parking equipment.

For more information, contact:

- California Department of Food and Agriculture's Fertilizer Research and Education Program
  (916) 653-5340
- California Fertilizer Association
  (916) 441-1584
- University of California Cooperative Extension

Monterey County:	Santa Clara County:
(831) 759-7350	(408) 299-2635

- County Agricultural Commissioner

Monterey County:	Santa Clara County:
(831) 759-7325	(408) 299-2171

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Water Management in Coastal Cool-Season Vegetables

Fact Sheet 3

Evaluate Current Irrigation and Fertilization Practices and Plan Improvements in Management

- Determine the extent of nitrate contamination of ground water beneath or near crop fields and assess the potential for transport of soluble contaminants (nitrate, salts) downward to the ground water and laterally to surface waters.
- Develop and implement a system for keeping long-term records on each field of water and nutrient/soil amendment inputs, cultural operations, pest problems, land leveling or other improvements, and crop yield and quality.
- Review current cultural practices and develop improved nutrient and water management plans.

Operate Irrigation Systems to Minimize Deep Percolation and N Losses

- Monitor soil moisture between irrigations and use the information to guide irrigation timing decisions.
- Base amount of water applied on crop need.
- Know the flow rate and the time required to apply the desired inches of water.
- Use the minimum leaching fraction to calculate the amount of water that will prevent yield reduction from salinity or stand establishment problems.
- When injecting fertilizer into irrigation water, follow all applicable government agency and industry guidelines for backflow prevention and regularly check and maintain backflow prevention devices.
- If irrigation efficiency remains low after all practical improvements have been made, as shown by an irrigation system evaluation, convert to a more efficient irrigation system.

Improve Existing Furrow Irrigation

- Convert to surge irrigation. Improve infiltration uniformity by turning irrigation water on and off as it flows down the furrow.
- If fields are more than 1000 feet long, consider cutting the furrow run length in half with a corresponding decrease in set time.
- Use high flow rates initially to get water down the field and then cut back to finish off the irrigation. Avoid doing the opposite.
- Prepare fields as uniformly as possible, with no major variations in slope.
- Use practices to increase uniformity among furrows (e.g., torpedoes, extra tractor trips, etc.).
- Collect surface runoff for recirculation or reuse elsewhere.

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Water Management in Coastal Cool-Season Vegetables

Fact Sheet 3

Improve Existing Sprinkler Irrigation

- Monitor flow and pressure variation throughout the system to detect non-uniform application.
- Maintain the irrigation system by repairing leaks, replacing malfunctioning sprinklers, and maintaining adequate water pressure through the entire set. Replace nozzles every three years and rebuild sprinkler heads every five years or as needed.
- To the extent possible, operate sprinklers during the least windy periods.
- Use offset lateral moves. Alternate the location of lateral pipes on successive irrigation events.
- When the pressure variation throughout the system is excessive, use flow control nozzles.
- Make set times as short as possible for stand establishment.
- For very large blocks, consider converting to linear move sprinkler system.

Improve Existing Drip Irrigation

- Use appropriate lateral hose lengths to improve uniformity.
- Use drip tape that has a small emitter discharge exponent.
- Check for clogging potential by conducting water analysis and fertilizer/water compatibility tests.
- Use filtration, chemical treatments, and flushing as necessary to prevent or correct clogging problems.

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Using the Nitrate Present in Soil and Water in Your Fertilizer Calculations

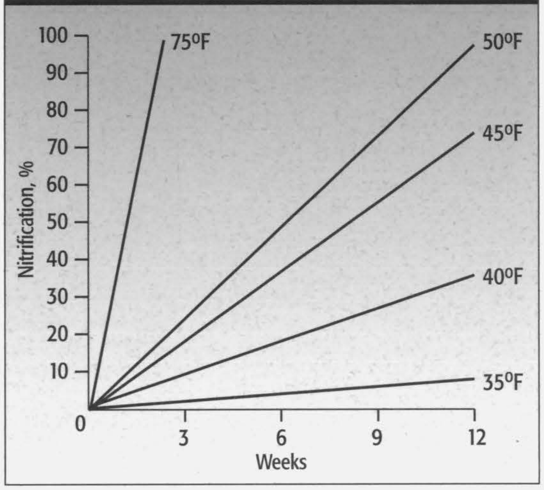
Fact Sheet 4

The information contained in this Fact Sheet is intended to help the grower reduce the amount of nitrogen fertilizer applied. A determination that irrigation water or soil is "high in nitrate" does not necessarily mean that it contains enough nitrate-nitrogen to eliminate the need for additional nitrogen fertilizer. However, by using this Fact Sheet, the grower may be able to replace a portion of the fertilizer normally applied with the nitrate-nitrogen already present in the soil or water.

N Availability

- Nitrate is the form of nitrogen used in a crop's growth cycle.
- Nitrogen that starts as urea or ammonia must go through a conversion to nitrate before it is available to the crop.
- Hydrolysis converts urea to ammonia in 3-5 days. **hy•dro•ly•sis** \hī-drä-lə-səs\ *n*: a chemical decomposition involving the addition of the elements of water.
- Nitrification converts ammonia to nitrate at a rate that depends on soil temperature (graph). **ni•tri•fi•ca•tion** \nī-trə-fə-kā-shən\ *n*: the oxidation (as by bacteria) of ammonium salt to nitrite and then to nitrate.

Generalized nitrification rates at various soil temperatures.



Conversion Factors In Water:

1 gallon of water	*weighs*	8.333 lbs
1 cu. ft. of water	*equals*	7.481 gallons

When You Know	***Multiply By***	***To Find***
acre-inches	27,150	gallons
acre-feet	325,850	gallons

When You Know	***Divide By***	***To Find***
gallons	27,150	acre-inches
gallons	325,850	acre-feet

When You Know	***Multiply By***	***To Find***
ppm NO_3	0.226	ppm NO_3-N
ppm NO_3-N	4.43	ppm NO_3

Conversion Factors In Soil:

When You Know	***Multiply By***	***To Find***
ppm NO_3-N	2	lbs N/acre (6" sample)
ppm NO_3-N	4	llbs N/acre (12" sample)
ppm NO_3	0.452	lbs N/acre (6" sample)
ppm NO_3	0.904	lbs N/acre (12" sample)

Equivalents:

1 mg/L	equals	1 ppm
1 unit N	equals	1 lb N/acre

All of the nitrate-nitrogen present in the soil or water is in a usable form; there are no inhibitors to plant uptake.

Percent Nitrogen Forms in Standard Nitrogen Solutions[i]

	Nitrate	Ammonia	Urea	lbs N/gal[1]	lbs/gal[2]
CAN-17	11.6	5.4		2.15	12.60
AN-20	10.0	10.0		2.10	10.50
UREA-20			20.0	1.87	9.33
UAN-28	7.0	7.0	14.0	2.98	10.66
UAN-32	7.8	7.8	16.4	3.54	11.06

[1] pounds of N per gallon of solution at 60°F

[2] material weight of solution at 60°F

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Using the Nitrate Present in Soil and Water in Your Fertilizer Calculations

Fact Sheet 4

Nitrogen Fertilizer Requirements of Cool-Season Vegetable Crops Grown Under California Conditions[ii]

Crop	Approximate Nitrogen Requirements (lb/acre-week)			
Broccoli[1]	Early Growth 5-15[2]	Mid Season 10-20	Button Formation 15-30	Head Development 10-20
Cabbage	Early Growth 5	Mid Season 35	Curling 40	Heading 55
Celery	Early Growth 5	Mid Season 15	Late Season 25	
Garlic	Early Growth 5	Mid Season 10	Bulbing 15	
Lettuce[1]	Early Growth 5-10	Cupping 10-20	Head Filling 15-30	
Onion	Early Growth 5	Mid Season 15	Bulbing 10	

[1] Values were determined when fertilizer was added through the drip irrigation system and should serve as a general guide, with fertilizer additions being subject to soil/tissue NO_3-N levels.

[2] Higher values represent N needs in low residual N soils and/or under rapid growth (high temperature) conditions.

Conversion Table for Nitrate in Irrigation Water

Nitrate (NO_3-N) ppm	Nitrate (NO_3) ppm	lb N/acre-inch	lb N/acre-foot
N (NO_3-N)	NO_3 = N x 4.43	lbs N/ac-in = N x 0.23	lbs N/ac-ft = N x 2.71
10	44	2	27
20	89	5	54
30	133	7	81
40	177	9	108
50	221	11	136
60	266	14	163
70	310	16	190
80	354	18	217
90	398	20	244
100	443	23	271
120	531	27	325
140	620	32	380
160	708	36	434
180	797	41	488
200	885	45	542
225	997	52	610
250	1107	56	678

The USEPA drinking water maximum contaminant level (MCL) for NO_3-N is 10 ppm; the MCL for NO_3 is 45 ppm.

Remember to take into account the efficiency of your irrigation system when crediting irrigation water N.

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[i] *Western Fertilizer Handbook: Second Horticulture Edition*. California Fertilizer Association.

[ii] *Production Guide: Nitrogen and Water Management for Coastal Cool-Season Vegetables*, 1998. G.S. Pettygrove, S.R. Grattan, B.R. Hanson, T.K. Hartz, L.E. Jackson, T.R. Lockhart, K.F. Schulbach, and R. Smith. Publication 21581, Division of Agriculture and Natural Resources, University of California, Oakland CA. This publication can be ordered from ANR Communication Services at 800-994-8849 or on the Internet at http://commserv.ucdavis.edu/ucce/.

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On-Farm Nitrogen Determination in Plant Sap, Soil, and Water

Fact Sheet 5

Plant Sap N Determination

Procedure

1. Sample a minimum of 20 plants from each field or management unit. See the chart below for the plant part to sample for each crop type. Always sample during the same time of day (preferably between 8 a.m. and 2 p.m.) to minimize variability.

Crop	Plant Part
Broccoli	Whole petioles (leaf stem) of youngest fully expanded leaf
Brussels Sprouts	Mid-rib of youngest fully expanded leaf
Cabbage	Mid-rib of wrapper leaf
Cauliflower	Mid-rib of youngest fully expanded leaf
Celery	Portion below first node of recently expanded leaf
Lettuce	Mid-rib of youngest fully expanded leaf
Spinach	Petiole of youngest mature leaf
Onion	Roots (washed with water and hand dried)

2. Avoid moisture loss from the tissue samples by keeping them in plastic bags on ice until analysis. Samples can be stored on ice for 6-8 hours without significantly affecting nitrate concentration.
3. Extract the sap from the selected plant part using a garlic press or plant press. Use the same amount of pressure to extract the sap from each of the 20 samples into a clean container. Mix and allow the sap to come to room temperature before analyzing.
4. A Cardy® nitrate meter or Merck Reflectoquant® Analysis System can be used to analyze the sap. Follow the respective meter directions for analysis. Samples may need to be diluted with distilled water if the nitrate concentration exceeds the testing capacity of the meter.

Interpretation

Nitrate-nitrogen (NO_3-N) sufficiency values for dry tissue and fresh sap samples

		NO_3-N Concentration	
Crop	**Growth Stage**	**Dry Tissue[1]**	**Fresh Sap**
Broccoli	mid-growth	10,000 - 20,000	1,000 - 1,600
	button formation	8,000 - 15,000	800 - 1,200
	preharvest	5,000 - 8,000	600 - 1,000
Brussels Sprouts	mid-growth	9,000	
	late growth	4,000	
Cabbage	10-12 leaves	8,000	
	mid-growth (folding)	6,000	1,200 - 1,500
	early heading	4,000	1,000 - 1,200
	preharvest	3,000	700 - 900 (mid heading)
Cauliflower	mid-growth (folding)	7,000	1,000 - 1,600
	button formation	6,000	
	curd development	2,500	700 - 1,000
	preharvest	1,500	500 - 800
Celery	mid-growth	7,000 - 10,000	600 - 800
	preharvest	6,000 - 8,000	400 - 600
Lettuce	early head formation	7,000 - 12,000	400 - 600
	preharvest	6,000 - 10,000	350 - 500
Spinach	mid-growth	8,000	
Onion	early bulbing	5,000 - 7,000	350 - 500

[1] Lab analyzed.

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On-Farm Nitrogen Determination in Plant Sap, Soil, and Water

Fact Sheet 5

Soil NO_3-N "Quick Test" Protocol

Procedure

1. Dissolve 5.6 grams of $CaCl_2$ in 1-gallon of distilled water to make 0.01 M $CaCl_2$ solution.
2. In a clean container, collect a composite soil sample that is representative of the main active root zone of the crop. Don't include the top 2 inches of soil since it may be high in NO_3-N but too dry for active root growth. Blend soil sample thoroughly.
3. Fill two 50-mL centrifuge tubes to the 30-mL level with the 0.01 M $CaCl_2$ solution. The calcium will help the soil settle to the bottom of the tube. (Duplicate samples—two tubes for each soil sample—are tested for each field to minimize the variability inherent in soil sampling.)
4. Add field-moist soil to the tube until the liquid level rises to 40 mL. Cap tightly and shake vigorously until the soil is thoroughly dispersed. Let sit until soil settles.
5. When the solution is reasonably clear, dip a Merckoquant® nitrate test strip into the solution for one second, shake off excess solution, and wait 60 seconds. Estimate nitrate concentration using the color chart provided.

Interpretation

The test strips measure the parts per million (ppm) nitrate (NO_3) in the solution. To approximate conversion of the reading to ppm nitrate-nitrogen (NO_3-N) for dry soil requires a correction factor based on soil texture and moisture.

test strip reading (ppm NO_3) ÷ correction factor = ppm NO_3-N in dry soil

Correction Factor		
Soil Texture	**Moist Soil**	**Dry Soil**
Sand	2.3	2.6
Loam	2.0	2.4
Clay	1.7	2.2

Levels less than 10 ppm NO_3-N would be considered low; levels above 20 ppm NO_3-N are adequate to meet immediate crop needs. Caution: Low soil NO_3-N levels late in the cropping season may not indicate insufficient N, rather they may indicate highly efficient crop uptake. Use plant tissue testing to confirm low N status.

Water N Determination

Procedure

1. Dip a Merckoquant® nitrate test strip into the water for one second, shake off excess solution, and wait 60 seconds. Estimate nitrate concentration using the color chart provided. (Note: concentrations can vary throughout the season.)

Strip reading (ppm NO_3) ÷ 4.43 = ppm NO_3-N

ppm NO_3-N x 1 inch x 0.227 = lbs of NO_3-N per acre-inch of water applied

A Merck RQflex® meter can be used to obtain more accurate color interpretations. Follow the meter instructions.

Monterey County Water Resources Agency

Santa Clara Valley Water District

These nitrate determination methods were excerpted from the University of California Division of Agriculture and Natural Resources "Production Guide: Nitrogen and Water Management for Coastal Cool-Season Vegetables." This publication can be ordered from ANR Communication Services at 800-994-8849 or on the Internet at http://commserv.ucdavis.edu/ucce/.

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On-Farm Nitrogen Determination in Plant Sap, Soil, and Water

Materials List and Ordering Information

Tools for N Test Procedures

"Quick-Test" Kits	individual test strips, calcium chloride, centrifuge tubes FREE while supplies last: Santa Clara Valley Water District . . . . (408) 265-2607, ext. 2723 Monterey County Water Resources Agency . . . .(831) 755-4860 University of California Cooperative Extension Offices Santa Clara County . . . . (408) 299-2635, ext. 4 Monterey County . . . .(831) 759-7350
Nitrate Test Strips	VWR Scientific Part No. EM-10020-1 $38.54 for pack of 100 Telephone (800) 932-5000
Calcium Chloride	VWR Scientific Part No. JT1332-1 $54.30 for 500 grams Telephone (800) 932-5000
Centrifuge Tubes	VWR Scientific Part No. 20171-034 $103.00 for case of 500 50-mL tubes Telephone (800) 932-5000
Soil Probes	JMC Soil Investigation Equipment Part No. 031 (12" samples) longer probes available Low cost sampler with foot pedal $56.65 (without foot pedal $31.45) Telephone (800) 247-6630
Cardy Nitrate Meter	Horiba Instruments Part No. 352343 $249.00 (includes standard solutions) Telephone (800) 446-7422
Merck Reflectoquant	VWR Scientific Part No. EM-16950-1 (meter) Part No. EM-16995-1 (nitrate test strips) $495.00 for RQflex meter $48.61 for nitrate test strips (test strips for other parameters are available) Telephone (800) 932-5000

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Fact Sheet 4 ***Using the Nitrate Present in Soil and Water in Your Fertilizer Calculations***

TABLES:

- N Availability At Various Soil Temperatures
- Conversion Factors In Water
- Conversion Factors In Soil
- Percent Nitrogen Forms In Standard Nitrogen Solutions
- Nitrogen Fertilizer Requirements Of Cool-Season Vegetable Crops Grown Under California Conditions
- Conversion Table For Nitrate In Irrigation Water

Fact Sheet 5 ***On-Farm Nitrogen Determination in Plant Sap, Soil, and Water***

METHODS:

- Plant Sap N Determination
- Soil NO_3-N "Quick-Test" Protocol
- Water N Determination

Materials List and Ordering Information

These fact sheets were produced jointly by the Monterey County Water Resources Agency and the Santa Clara Valley Water District with partial funding through the United States Environmental Protection Agency section 319(h) Grant Funds, Agreement #7-116-253-1. Technical translation to Spanish was graciously provided by Maria de la Fuente, Ph.D., Farm Advisor with the University of California Cooperative Extension in Santa Clara County, and German Criollo and Manuel Saavedra with the Monterey County Water Resources Agency.

Monterey County Water Resources Agency

Manages, protects, and enhances the quantity and quality of water and provides specified flood control services for present and future generations of Monterey County.

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